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ISSN 0543-5846
METABK 52(1) 32-34 (2013)
UDC – UDK 621.778.001.5=111

ANALYSIS THE INFLUENCE OF DRAWING PROCESS PARAMETERS ON THE AMOUNT OF RETAINED AUSTENITE IN TRIP STEEL WIRES

Received – Prispjelo: 2012-03-21
Accepted – Prihvaćeno: 2012-07-30
Original Scientific Paper – Izvorni znanstveni rad

The paper presents a theoretical analysis of the process of drawing TRIP-effect steel wires involving simulation of the drawing process. The process was run following two variants, with small and large partial drafts for three drawing speeds: 1,11; 0,23 and 0,005 m/s. The investigations carried out allowed a relationship between the amount of retained austenite and strain intensity and strain rate to be established for TRIP steel wires drawn.

Keywords: drawing, TRIP steel, wires, austenite

INTRODUCTION

The drawing process is a complex process, in which the selection of optimal parameters, i.e. drawing speed and the magnitudes of partial drafts and total draft, significantly influences the properties of finished wire [1,2].

Published research on high-alloy austenitic TRIP steels has indicated an effect of strain intensity, strain rate, chemical composition and deformation temperature on the effectiveness of the martensitic transformation [3].

ORIGINAL INVESTIGATION

The investigation involved carrying out a theoretical analysis of the drawing process by means of process simulation using Drawing 2D, a finite elements method-relying software program.

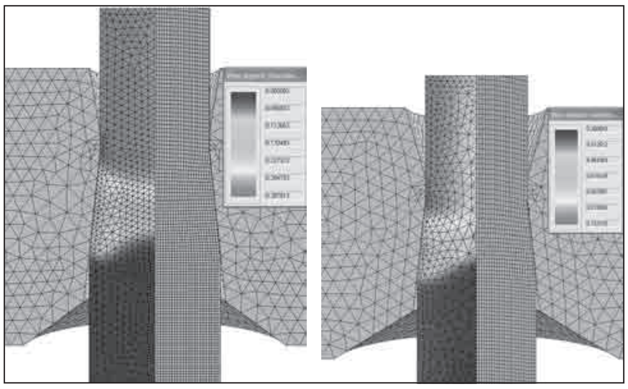
The drawing process was conducted following two variants, with either small or large partial drafts (Table 1), for three drawing speeds: 1,11; 0,23 and 0,005 m/s. A friction coefficient value of μ = 0,06 (the conventional drawing process) and the 2α drawing angle equal to 12 ° were assumed.

The investigation enabled the determination of the strain intensity distribution for TRIP steel wires in particular draws for different drawing speeds. Figure 1 represents example strain intensity distributions in wires drawn with large partial drafts, at a high drawing speed of 1,11 m/s.

From the nodes of the finite element grid, the values of strain intensity of wire on exit from the drawing die sizing part were red out, while the strain rate was calculated from the formula for the mean strain rate in the die approach part, as represented by the formula below (1):

Table 1 **A summary of partial drafts and the total draft used for wire drawn from ϕ 6,25 mm to ϕ 4,46 mm**

Wire diameter /mm	6,25	5,60	5,20	4,80	4,46
Variant 1 G_{cz} / %	-	18,41	13,77	14,79	13,66
Variant 2 G_{cz} / %	-	-	29,65	-	26,43
G_c / %	-	18,41	29,65	40,06	48,25



Draw 1 Draw 2

Figure 1 Strain intensity distribution in wires drawn with large partial drafts and a drawing speed of 1,11 m/s

$$\dot{\varepsilon}_{Hm} = \frac{6 v_c tg\alpha \ln\lambda}{d_k\left(\lambda - \frac{1}{\sqrt{\lambda}}\right)} \quad (1)$$

where: v_c – drawing speed, λ - elongation factor,
d_k – final wire diameter

Retained austenite volumetric fractions of the structure of wire rod and wires after the process of drawing with either small or large partial drafts and three drawing speeds, as determined in previous experimental tests

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[4], were assigned to respective values of strain rate and strain intensity.

Results illustrating the amount of retained austenite (ν_γ) as a function of strain intensity on the surface and in the axis of drawn wires, for different strain rates, are given in Tables 2÷5.

Table 2 **The amount of retained austenite (ν_γ) as a function of strain intensity and different strain rates on the surface of wires drawn with small partial drafts**

ε	$\dot{\varepsilon}$ /s^{-1}	ν_γ /%
0	0	23,95
0,24	78,57	10,31
0,39	86,53	7,50
0,55	93,02	6,15
0,69	99,99	5,31
0,19	16,28	13,32
0,32	17,93	11,50
0,44	19,27	9,10
0,55	20,72	7,90
0,17	0,35	15,37
0,28	0,38	12,65
0,39	0,41	10,02
0,48	0,42	8,98

Table 3 **The amount of retained austenite (ν_γ) as a function of strain intensity and different strain rates in the axis of wires drawn with small partial drafts**

ε	$\dot{\varepsilon}$ /s^{-1}	ν_γ /%
0	0	23,95
0,21	78,57	12,82
0,35	86,53	10,12
0,51	93,02	8,14
0,65	99,99	6,54
0,16	16,28	15,21
0,27	17,93	13,60
0,39	19,27	11,20
0,49	20,72	8,62
0,14	0,35	17,26
0,20	0,38	14,91
0,31	0,41	12,06
0,45	0,42	10,12

Table 4 **The amount of retained austenite (ν_γ) as a function of strain intensity and different strain rates on the surface of wires drawn with large partial drafts**

ε	$\dot{\varepsilon}$ /s^{-1}	ν_γ /%
0	0	23,95
0,39	80,64	6,65
0,72	96,09	4,94
0,36	16,71	10,98
0,64	19,91	6,24
0,30	0,36	11,95
0,59	0,43	8,02

Based on the results given in Table 2÷5 and after making the approximating with a function of two variables, relationships have been obtained, which define the amount of retained austenite as a function of ε and $\dot{\varepsilon}$ (Figures 2÷5).

Table 5 **The amount of retained austenite (ν_γ) as a function of strain intensity and different strain rates in the axis of wires drawn with large partial drafts**

ε	$\dot{\varepsilon}$ /s^{-1}	ν_γ /%
0	0	23,95
0,35	80,64	9,14
0,65	96,09	5,06
0,30	16,71	12,04
0,54	19,91	7,41
0,24	0,36	13,06
0,43	0,43	9,14

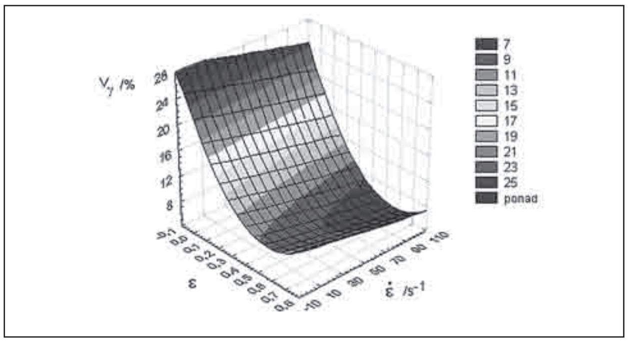

Figure 2 The plane representing the relationship between the retained austenite percentage fraction of the structure and strain intensity and strain rate on the surface of TRIP steel wires drawn with small partial drafts

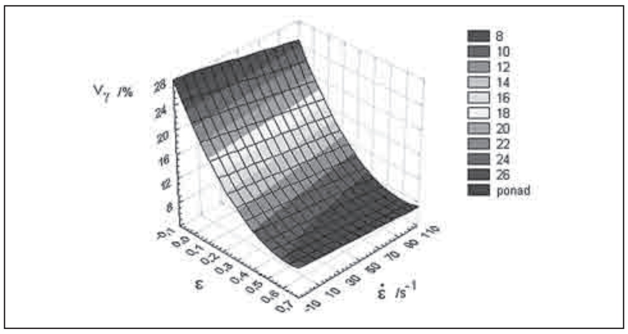

Figure 3 The plane representing the relationship between the retained austenite percentage fraction of the structure and strain intensity and strain rate in the axis of TRIP steel wires drawn with small partial drafts

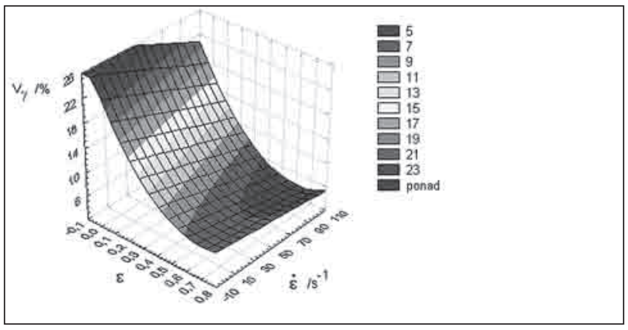

Figure 4 The plane representing the relationship between the retained austenite percentage fraction of the structure and strain intensity and strain rate on the surface of TRIP steel wires drawn with large partial drafts

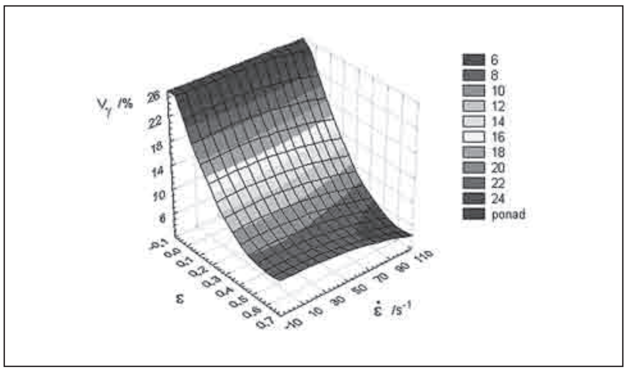

Figure 5 The plane representing the relationship between the retained austenite percentage fraction of the structure and strain intensity and strain rate in the axis of TRIP steel wires drawn with large partial drafts

CONCLUSIONS

Figures 2÷5 show that, in the drawing process, strain intensity has a definite effect on the amount of transformed retained austenite in the wire structure. By examining the data in Figures 2 and 4, a small effect of strain rate on the decrease in the amount of transformed retained austenite in the wire sub-surface layer and its virtually insignificant effect in the wire axis can be found. This is probably caused not so much by the action of strain rate (whose difference between the wire surface and axis is small) as by the larger non-dilatational strain occurring at a higher strain rate.

The acceleration of the transformation of retained austenite into martensite in the drawing process is predominantly influenced by the magnitude of partial drafts.

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Note: The professional translator for English language is Czesław Grochowina, Studio – Tekst, Poland